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THE UNIVERSITY OF ALBERTA
"A PARENT MATERIAL STUDY OF TWO SOLONETZIC SOIL
SEQUENCES IN SOUTHERN ALBERTA"

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

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by

R.E. WELLS, B.Sc.

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ABSTRACT

On the basis of field examination, eight soil series were tentatively assumed to fall within two separable catenas having morphologically similar member profiles. The objectives of the study were to determine firstly, whether or not the catena separation was justified, and secondly, whether or not the degree of solonetzic development could be attributed to variations in composition of parent materials.

The four soil series within each of the two catenas were sampled in the field, and chemical, physical and mineralogical analyses were conducted on the samples in the laboratory.

Mineralogical and physical data obtained for the parent materials failed to differentiate either the two suggested catenas or the member profiles. Differences in lime content of parent materials between some of the corresponding member profiles partially justified the recognition of two separate catenas.

Laboratory data obtained for the soil sola corroborated the separation of the soil series sampled into different member profiles.

The variation in morphology between the Orthic and Solonetz-like member profiles as compared to the Solodized-Solonetz and Solod member profiles appeared to be largely due to the difference in total amount of soluble salts in the parent materials.

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INTRODUCTION

Pedology was first systematized by acceptance of the concept that climate, organisms, parent material, relief and age were the five environmental factors affecting soil formation. Many studies in soil genesis and classification have dealt with evaluation and interrelation of one or more of the five factors in the formation of different soils. This study attempts to assess the importance of the parent material factor in the formation of Solonetzic soils of Southern Alberta and to apply the results to clarify certain problems in field mapping.

The present study is concerned with eight soil profiles obtained from a transitional area lying between the Brown and Dark Brown soil zones. The soil series represented by these profiles have been mapped and described by the Alberta Soil Survey in the course of field work.

The soil series included in the present study are considered to fall within two separable catenas having morphologically similar members. The catenas are distinguished here as Catena A and Catena B, with comparable members grouped as follows:

<u>Member Profile</u>	<u>Catena A</u>	<u>Catena B</u>
Orthic	Maleb	Hanalta
Solonetz-like	Malez	Dowling
Solodized-Solonetz	Hemaruka	Parr
Solod	Halliday	Earltown

The study was undertaken to determine firstly, whether or not any chemical, physical, or mineralogical differences in composition of the parent materials could be found to justify the suggested separation of the sampled profiles into two catenas; and secondly, to determine whether or not the degree of solonetzic development could be attributed to variations in parent material composition. For this purpose the four soil series within each of the two catenas were sampled in the field and brought into the laboratory for analysis.

REVIEW OF LITERATURE

Parent material studies conducted elsewhere have employed a variety of approaches and analytical methods in establishing the relationship between morphology of the soil solum and characteristics of the underlying material. A review of literature concerned with such studies aided in the selection of the proper approach for investigating the relationship between some Solonetzic soils and glacial till materials of southern Alberta.

Application of Mineralogical Analyses to Study of Soil Parent Materials

Various mineralogical analyses have been used to study the origin and development of soils. Some of the applications of these analyses to the characterization of soil parent materials are worthy of discussion.

Lithology of the coarse fractions in parent material has been used as an indication of the degree of weathering in the soil skeleton. Ehrlich et al. (7) determined the percentages of various rock particles in individual horizons and in the parent materials of ten profiles formed on Mankato till. The rate of weathering of the coarse fractions (2-50 mm.), as shown by these percentages, was concluded to be: shale > limestone > other rock fragments.

Haseman and Marshall (11) outlined a semi-quantitative method for using the presence of heavy minerals to identify parent materials. It was concluded that the kinds and amounts of heavy minerals present reflect the origin of the soil. A qualitative determination of heavy minerals was suggested as sufficient to indicate the source of soil parent material after the kind and the abundance of the minerals have been determined in possible parent materials. The same size fractions were used in making heavy mineral comparisons between soil sola and parent materials. Variations in the origin of parent materials at different depths were shown by the heavy mineral analyses.

Marshall and Jeffries (15) explained a mineralogical method for correlating soil types and parent materials. The very fine sand and silt size separates were used in their study. The size fractions were separated by means of heavy liquids into three specific gravity fractions:

heavy minerals (>2.95 sp.gr.), micas ($2.95 - 2.70$ sp.gr.), feldspars and quartz (<2.70 sp.gr.). The minerals were mounted on a gelatin slide and determined using standard petrographic methods. Application of the method indicated that three size fractions should be examined separately and together due to the possibility that a mineral may weather out of a finer before disappearing from a coarser fraction.

Bayrock (4) reporting on a study of the Viking and Coteau tills of East - Central Alberta concluded that mineralogical, mechanical, and x-ray analyses conducted on the two tills showed no major discontinuity in their composition. Individual soil profiles developed on the two tills did not reveal any appreciable weathering of silicates in the upper soil horizons.

Ehrlich et al. (7), reporting on the influence of the composition of parent materials on soil formation in Manitoba, concluded that montmorillonite and illite were the dominant clay minerals found in all the representative genetic soil types in both grassland and forested regions except in the case of the Brown Podzolic and Podzol types. Iron oxides were found to be important clay components in the Brown Podzolic soil, and feldspars were present in greater proportion in the clay of the Podzol soil than in other types.

Warder and Dion (31) found that the clay minerals of

the one micron and finer size fraction in some Saskatchewan soils were roughly a mixture of equal parts of montmorillonite and illite. It was concluded that the mineralogical nature of this clay size fraction of the Saskatchewan soils was very similar to that of the parent materials, and was probably inherited from shales which have been important as sources of the parent materials of Saskatchewan soils.

Rice et al. (19), in a mineralogical study of three soil profiles from Saskatchewan and two from Alberta, showed that the predominant clay minerals were montmorillonite and illite. The three Saskatchewan profiles were almost identical from a mineralogical viewpoint. The two Alberta profiles were found to differ from the Saskatchewan profiles in several aspects, such as having slightly more quartz and considerably less feldspars in the silt and clay fractions. The clay fractions of one Alberta profile were all very high in illite; the fine fractions had more illite than montmorillonite whereas the fine fractions of the other profiles were almost totally composed of montmorillonite.

Forman and Rice (10) demonstrated the value of mineralogical analyses for identification of the origin of soil parent materials. The study of some core samples from the Bearpaw geological formation showed marked similarities between the mineralogical composition of the Bearpaw shales and that of some of the soils of southern Saskatchewan and

southern Alberta.

Mineralogical analyses have undoubtedly been a valuable tool in studies of the origin and development of soils. Such analyses have enabled both the determination of the degree of weathering in soils and more adequate characterization of soil parent materials.

Role of Physical Analyses in Parent Material Studies

Wascher and Winters (32) reported on a study of textural relationships between soil sola and parent materials. The study of textural groups of Wisconsin till and their distribution in Illinois showed the clay content of the till to vary in a nearly continuous manner from less than 10 per cent to more than 50 per cent. Field observations indicated a close correlation between the mechanical composition of the till and soil properties, a conclusion substantiated by Stauffer (28) in the laboratory. As a result of these studies four soil series were recognized as being developed from tills of medium, medium heavy, heavy, and very heavy textures. Field-mapping problems in the area were greatly clarified by the studies leading to recognition of the textural sequence mentioned above.

Other physical characteristics have been shown to be important in classifying soils into series. Smith et al. (25), in a discussion of the Prairie soils of the upper Mississippi valley, reported on the usefulness of parent

material porosity as an accessory characteristic for differentiation of two minimal Prairie soils which lacked textural profiles. The Monona soils were developed from nearly sand-free loess which had an apparent specific gravity of 1.3. The Clarion soils were developed from Wisconsin till which had about the same clay content as the loess but 30 to 50 per cent sand and an apparent specific gravity of 1.5. Variations in parent material porosity between these two soils were shown to be of practical importance in the design of terrace systems for run-off control. The study related management and land use for the soil series on the basis of porosity and justified the recognized separation on the series level.

In the above studies physical analyses were found to be helpful in classification of the soils concerned.

Statistical Approach to Study of Soil Parent Materials

Allen and Whiteside (1) demonstrated the value of a statistical approach for relating the characteristics of certain soils and parent materials. Field and laboratory studies were conducted on well drained soils and associated tills of the Cary and Mankato substages of the Wisconsin drift in Sanilac County, Michigan. Soils on the older Cary till were shown to be deeper, more acid, and more clearly differentiated into horizons than soils on the Mankato till. A sufficient number of sample sites were chosen from the

moraines of each substage to enable a statistical comparison of carbonate content, depth of leaching, and mechanical analysis data. The mean carbonate content and the depth of leaching of the Mankato till were 31.4 per cent and 20 inches respectively. The mean carbonate content and the depth of leaching of the Cary till were 22.4 per cent and 29 inches respectively. The mechanical analyses of the till samples did not reveal any statistically significant differences in particle size distributions in the two drifts.

Bayrock (4) stated that in the case of soils in arid climates the zone of lime accumulation is near the surface, and consequently, it is doubtful whether depth of leaching measurements can be applied to such soils for the purpose of outlining glacial boundaries in many of the western areas of North America.

From the foregoing, statistical methods were helpful in one case but not applicable in the other. Numerous replications of series are required for such an approach.

Parent Material Studies Involving Chemical Analyses

Application of chemical analyses for characterization of soils and parent materials has supplied useful data for purposes of soil classification. Some of the chemical analyses in use are evaluated in the following discussion.

Ehrlich et al. (7) reported on an investigation of ten profiles (including Black Earths, Rendzina, Grey Wooded, Brown Podzolic, and Podzol soils) in relation to parent

material and environment on well drained sites of similar relief. The results showed the marked effect of chemical composition, especially the percentage of inorganic carbonates in the parent materials, on profile development. Shallow profiles were developed on very high-lime materials. The calcium carbonate content of the parent material was concluded to be an important factor in determining the extent to which organic colloids were precipitated and retained in the B horizon.

Data from total chemical analyses of soils have been used to indicate the degree of weathering of soils with respect to parent materials. Ehrlich et al. (7) determined total chemical composition, by horizon depths, to suggest that weathering in grassland soils was confined to the release of calcium and magnesium, while in the forest soils, less soluble constituents, especially iron, were released. Shawarbi (24) emphasized that although total chemical analysis is used in connection with methods for estimating the degree of weathering of soils, the resulting data is of small value because of failure of the method to distinguish between the unweathered minerals and the weathering complex. The use of total chemical analyses for characterization of parent materials would be limited by failure of the method to distinguish between the clay and non-clay portions.

Determinations of soluble salt composition have been utilized to supply data for pedological studies of Solonchic soils. Ehrlich and Smith (8) showed that water soluble sodium was equal to or greater in quantity than water soluble calcium or magnesium in the principal horizons of eleven halomorphic profiles. Water soluble sodium was concluded to be one of the principal constituents in the salinization stage of the eleven profiles even though exchangeable sodium in excess of fifteen per cent of the exchangeable cations was found only in some horizons.

The above examples give some illustration of the usefulness of chemical analyses for the study of relations between soils and parent materials. The value of any chemical data is greatly increased when chemical methods are combined with other methods of soil characterization.

MATERIALS AND METHODS

Description of the Sample Area

The soil profiles which were sampled for this study occur in Alberta map sheet 72 M. The map sheet is located between 51° and 52° north latitude and between 110° and 112° west longitude.

The parent materials for the soil series concerned in this study are primarily glacial till deposits of varying depth. Stalker (27) states that the surficial material in central Alberta is generally thin, particularly so in comparison with that to the east in Saskatchewan. The

relative thinness of the surficial material is believed to be the result of a shorter period of occupation by glaciers in Central Alberta, perhaps fewer major glaciations and thinner ice, with consequently less glacial erosion and deposition. The ground moraine within the region is generally less than 20 feet thick, while the drift composing the hummocky moraine is generally 20 to 50 feet thick. The soil series concerned in this study occur in both ground and hummocky morainal areas.

The vegetation in the transitional area between the Brown and Dark Brown soil zones is primarily comprised of various grass species. Blue grama grass (Bouteloua gracilis) and common spear grass (Stipa comata) are the more common grasses in drier topographic positions, while June grass (Koeleria cristata) and bluejoint (Agropyron Smithii) are more dominant in the moist positions. Patches of buck brush (Symphoricarpos occidentalis) occur throughout the area.

The climate of the area is semi-arid. The mean annual precipitation is about 13 inches of which 75 to 80 per cent falls in the seven month period between April and October. About 15 per cent of the precipitation comes in individual rains of 0.2 inches or less. The average annual moisture deficiency calculated on the basis of Thornthwaite's equations is reported to be about 10 inches (13). The mean average temperature for the area in the period from April to October is 52.5°F. July is the warmest month with a mean

average temperature slightly over 64°F. The vegetative period begins about April 22 and ends October 15.

Description of Soil Samples

The soil areas sampled for this study are described in detail. The classification of soil series is based on the nomenclature adopted for soil survey purposes as advanced by the National Soil Survey Committee (18). The designation of soil horizons is in accordance with the designations outlined in the U.S.D.A. Soil Survey Manual (26). Color descriptions are given on an air dry basis and are in accordance with the Munsell system of color notation (26). Textural classes are based on data obtained from mechanical analyses. All of the profiles sampled were considered to be modal for their respective series.

SOIL SERIES OF CATENA A

Maleb Loam - Orthic Brown developed on till.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁	0-2	Brown (10YR 4/3) sandy clay loam; weak prismatic which breaks into weak medium granular structure.
B ₂	2-10	Brown (10YR 5/3) sandy clay loam; moderate medium prismatic structure.
Cca	10-18	Light grey (10YR 7/2) sandy clay loam; weak medium prismatic structure.
C ₁	18-36	Light brownish grey (10YR 6/2) sandy clay loam; massive structure.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
Csa	44-48	Grey brown (10YR 5/2) clay loam; massive structure; spotted with accumulations of salts and gypsum.
C ₂	72-78	Brown (10YR 5/3) clay loam; massive structure.

C ₃	at 150	Grey brown (10YR 5/2) loam; massive structure.
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Malez Loam - Solonetz-like Brown developed on till.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁	0-3	Brown (10YR 5/3) clay loam; weak prismatic which breaks into weak medium granular structure.
B ₂	3-13	Brown (10YR 4/3) clay loam; moderate medium prismatic which breaks into strong medium subangular blocky structure.
Cca	13-18	Pale brown (10YR 6/3) clay loam; weak medium prismatic structure.
C ₁	18-36	Brown (10YR 5/3) sandy clay loam; massive structure; spotted with carbonates.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
C ₂	48-52	Brown (10YR 5/3) loam; massive structure; less limy than C ₁ horizon.

C ₃	at 126	Brown (10YR 5/3) loam; massive structure; selinite crystals common.
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Hemaruka Loam - Brown Solodized-Solonetz developed on till.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁	0-3	Yellowish brown (10YR 5/4) sandy loam; weak coarse prismatic which breaks into weak medium granular structure.
A ₂	3-6	Pale brown (10YR 6/3) sandy loam; weak coarse prismatic which breaks into thin platy structure.
B ₂	6-9	Very dark grey brown (10YR 3/2) clay; strong coarse round-top columnar which breaks into strong medium blocky structure.
B ₃	9-15	Dark grey brown (10YR 4/2) clay; strong medium blocky structure.
Cca	15-26	Grey brown (10YR 5/2) silty clay to clay; moderate medium blocky structure.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
C ₁	at 26	Light brownish grey (10YR 6/2) sandy clay loam; massive structure; salt accumulations common.

C ₂	at 72	Brown (10YR 5/3) sandy clay loam; thick platy which breaks into strong medium blocky structure; unconsolidated argillaceous sandstone.

Halliday Loam - Brown Solod developed on till.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁	0-12	Dark yellowish brown (10YR 4/4) loam; weak coarse prismatic which breaks into weak medium platy structure.
A ₂	12-15	Brown (10YR 5/3) sandy loam; weak coarse prismatic which breaks into thin platy structure.
B ₂	15-19	Dark grey brown (10YR 4/2) silt loam; strong medium round-top columnar which breaks into medium subangular blocky structure; clay films on ped surfaces; some stones.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
Cca	19-25	Yellowish brown (10YR 5/4) sandy clay loam; massive structure.
C ₁	at 30	Very dark grey brown (10YR 3/2) sandy clay loam; massive structure.

C ₂	at 138	Brown (10YR 5/3) loam; massive structure; no evidence of salts.

SOIL SERIES OF CATENA B

Hanalta Loam - Orthic Dark Brown developed on a mixture of banded silts, clays and till.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁	0-6	Dark grey brown (10YR 4/2 - 3/2) loam; weak coarse prismatic which breaks into weak medium granular structure.
B ₂	6-15	Brown (10YR 4/3) sandy clay loam; moderate medium prismatic which breaks into small subangular blocky structure.
Cca	15-33	Light brownish grey (10YR 6/2 - 6/3) loam to sandy clay loam; weak coarse prismatic.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
C ₁	at 40	Pale brown (10YR 6/3) clay loam; banded, varved and layered.
D ₁	at 60	Pale brown (10YR 6/3) sandy clay loam; massive structure; spotted with salt accumulations.

D ₂	at 144	Pale brown (10YR 6/3) sandy loam to sandy clay loam; massive structure.
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Dowling Loam - Solonetz-like Dark Brown developed on water-sorted till.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁	0-4	Dark grey brown (10YR 4/2 - 4/3) sandy loam; weak medium prismatic which breaks into weak medium granular structure.
B ₂	4-12	Brown (10YR 4/3) clay loam; moderate medium prismatic which breaks into strong fine blocky structure.
Cca	12-20	Light brownish grey (10YR 6/2) clay loam; weak medium prismatic which breaks into moderate fine blocky structure.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
C ₁	at 20	Light brownish grey (10YR 6/2) clay loam; massive structure; banded appearance.
D ₁	at 48	Dark grey brown (10YR 4/2) clay loam; massive structure.

D ₂	at 138	Brown (10YR 5/3) sandy clay loam; massive structure.

Parr Loam - Dark Brown Solodized-Solonetz developed on water-sorted till.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁	0-10	Dark brown to brown (10YR 4/3) sandy loam; weak coarse prismatic which breaks into weak medium granular structure.
A ₂	10-12	Pale brown (10YR 6/3) sandy loam; weak coarse prismatic which breaks into thin platy.
B ₂	12-16	Dark grey brown (10YR 4/2) sandy clay loam; strong coarse blocky which breaks into strong medium blocky structure; clay films on ped surfaces; round-tops common.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
B ₃	16-24	Dark yellowish brown (10YR 4/4) sandy clay loam; weak coarse blocky which breaks into weak subangular blocky.
Cca	24-31	Brown (10YR 5/3) sandy clay loam; massive structure.
C ₁	31-40	Brown (10YR 4/3 - 5/3) loam to clay loam; massive structure; water-sorted till.

C ₂	at 132	Brown (10YR 5/3) loam to clay loam; massive structure.
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Earltown Loam - Dark Brown Solod developed on water-sorted till or alluvial material.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁₁	0-6	Very dark grey brown (10YR 3/2) loam; weak coarse prismatic which breaks into weak medium granular structure.
A ₁₂	6-14	Brown (10YR 4/3) loam; weak coarse prismatic which breaks into medium platy structure.

<u>Horizon</u>	<u>Depth, Inches</u>	<u>Description</u>
A ₁₃	14-19	Dark brown (10YR 3/3) silt loam; weak coarse prismatic which breaks into medium platy structure.
A ₂	19-21	Light brownish grey (10YR 6/2) silt loam; weak coarse prismatic which breaks into thin platy.
B ₂	21-27	Brown (10YR 5/3) loam to clay loam; moderate medium prismatic which breaks into medium subangular blocky and medium platy structure.
C	34-42	Brown (10YR 5/3) sandy loam; massive structure; no evidence of salts.

D	at 72	Light grey (10YR 7/1) sandy loam to loamy sand; weakly consolidated sandstone.

Laboratory Methods

The soil samples were air dried and ground to pass through a 2 mm. sieve. Each sample was thoroughly mixed and held in a glass screw-top container until needed for analysis.

Mineralogical Analyses

The C₁ horizon samples of the soil profiles were

subjected to the following separations and analyses.

1. Initial treatment and separation of sand and clay in preparation for mineralogical analyses:
 - (a) addition of normal HCl to remove carbonates;
 - (b) treated with H_2O_2 to destroy organic matter;
 - (c) washed to remove soluble salts;
 - (d) wet sieved to separate the 150 - 100 micron sand fraction; and
 - (e) separation of total clay by sedimentation.
2. Total clay fractions from above were separated into "coarse" (2.0 - 0.2 microns) and "fine" (<0.2 microns) portions by centrifuging.
3. Heavy liquids were used to obtain the light sand (sp.gr. <2.70) sub-fractions from the 150 - 100 micron sand fractions. The light sand sub-fractions were ground to pass a 300 mesh sieve; and x-ray diffraction patterns obtained for the powder samples.
4. The coarse and fine clay fractions were flocculated with 25 ml. of a saturated calcium chloride solution; prepared as orientated glass slides; and x-ray diffraction patterns obtained after:

- (a) air drying;
- (b) treatment with ethylene glycol; and
- (c) heating to 550°C.

A Norelco high angle, geiger counter x-ray spectrometer with a copper target was used to examine the light sand and the clay fractions.

The mineralogical determinations provided data for comparison of parent materials of the soil profiles.

Physical Analyses

Mechanical analyses were carried out on all samples according to the modified procedure for pipette analysis by Toogood and Peters (30). Hydraulic conductivity measurements on the disturbed soil samples were determined according to the procedure outlined in the U.S.D.A. Handbook 60 (12). The physical analyses provided data for comparisons of parent materials and sola of the different soil profiles.

Chemical Analyses

The pH values of saturated pastes of the soil samples were measured with a Beckman Model H-2 pH meter.

Soluble salt analyses were carried out on the saturated water extracts of the soil samples according to the procedure outlined in U.S.D.A. Handbook 60 (12). Soluble salt determinations were omitted for the samples of A horizons because low electrical conductivities of saturated extracts indicated very small amounts of soluble salts in

those horizons.

Exchangeable metallic cations were extracted from the air dry soil samples with neutral, normal ammonium acetate (16). Exchangeable calcium, magnesium, sodium, and potassium were determined with the Beckman Model DU flame spectrophotometer according to a modification of the procedure described by Baker (3). The cations were determined in the ammonium acetate extract with the addition of cleaning solution as proposed by Choinière (6). Total exchange capacity was determined by extraction of adsorbed ammonia with normal sodium chloride solution and distillation of the extract according to the magnesium oxide method for ammoniacal nitrogen (16). Exchangeable acidity was determined by leaching separate soil samples with neutral, half normal barium acetate and using tenth normal sodium hydroxide to titrate the extract to an end point with phenolphthalein indicator (21). Exchangeable acidity data were reported as exchangeable hydrogen values. Exchangeable cations were determined for all samples which had no appreciable inorganic carbonate content.

Total nitrogen values of the solum samples were determined by a macro Kjeldahl method similar to that outlined by Prince (17). The ammonia was distilled into four per cent boric acid solution.

Organic carbon was determined by the dry combustion

method outlined in the A.O.A.C. methods of analysis handbook (16). Inorganic carbon was determined in the soil samples by a modified method of Schollenberger (22). The carbon dioxide was evolved by heating the sample in dilute sulfuric acid containing ferrous sulfate. Inorganic carbon data have been reported as per cent calcium-carbonate-equivalent values.

The procedure for determination of major chemical constituents of the parent clay and light sand fractions was essentially that outlined by Atkinson et al. (2). Sodium hydrosulfite was used to remove "free" iron oxide from the clay samples according to the procedure described by Mackenzie (14). Iron was determined colorimetrically with orthophenanthroline as outlined by Shapiro and Brannock (23). The above chemical analyses supply most of the data for comparison of solum samples, and in addition, form a useful supplement to the mineralogical analyses.

RESULTS AND DISCUSSION

Clay Mineral Distribution in the C₁ Horizons

The results for x-ray diffraction analyses of the two clay fractions from the C₁ horizons of each soil profile are shown in Table I. Montmorillonite and illite appear to be the major clay minerals present in the coarse clay fractions, while montmorillonite is the dominant clay mineral of the fine clay fractions. The data show a marked similarity in

TABLE I - CLAY MINERAL DISTRIBUTION IN THE C₁ HORIZONS OF THE PROFILES

Series	2 - 0.2 microns						<0.2 microns						
	Qtz.	Feld.	Mont.	Illite	Kaol.	Chlorite	Qtz.	Feld.	Mont.	Illite	Kaol.	Chlorite	
Catena A													
Maleb	Min.	Tr.	Maj.	Maj.	Min.	None	Tr.	None	Dom.	Min.	- Maj.	Tr.	None
Malez	Min.	Tr.	Maj.	Maj.	Min.	None	Tr.	None	Dom.	Min.	- Maj.	Tr.	None
Hemaruka	Min.	Tr.	Maj.	Maj.	Min.	Tr.	Tr.	None	Dom.	Min.	- Maj.	Tr.	None
Halliday	Min.	Tr.	Maj.	Maj.	Min.	None	Tr.	None	Dom.	Min.	- Maj.	Tr.	None
Catena B													
Hanalta	Min.	Tr.	Maj.	Maj.	Min.	Tr.	Tr.	None	Dom.	Min.	- Maj.	Tr.	None
Dowling	Min.	Tr.	Maj.	Maj.	Min.	Tr.	Tr.	None	Dom.	Min.	- Maj.	Tr.	None
Parr	Min.	Tr.	Maj.	Maj.	Min.	Tr.	Tr.	None	Dom.	Min.	- Maj.	Tr.	None
Earltown	Min.	Tr.	Maj.	Maj.	Min.	None	Tr.	None	Dom.	Min.	- Maj.	Tr.	None

Dominant
Major
Minor
Trace

70 - 100%
40 - 70%
10 - 40%
0 - 10%

the composition of minerals comprising the two clay fractions in the C₁ horizons of the different soil profiles. Some of the soil profiles have trace amounts of chlorite in the coarse clay fractions. However, the small differences in chlorite content seem to be random. It can be said that the data show no distinguishable variations between the two suggested catenas, and the different member profiles appear not to be separable on the basis of clay mineral distribution in the parent materials.

Chemical Analyses of the Two Clay Fractions

The chemical analyses of the two clay fractions from the C₁ horizons of the soil profiles are presented in Table II. The high proportions of montmorillonite in the fine clay fractions as revealed by x-ray examination are verified by low silica-sesquioxide ratios and high total exchange capacities as shown in the chemical data. Percentages of total silica, iron, aluminum, calcium, magnesium, potassium, and the percentages of "free" iron oxide show as much variation in the clay fractions within each of the suggested catenas as between the two catenas. The molecular ratios for the total silica, aluminum, and iron, and the total exchange capacities likewise show as great a variation within each catena as between the two catenas. The data therefore do not distinguish between the two suggested catenas on the basis of chemical composition of the two clay fractions in the parent materials.

TABLE II - CHEMICAL ANALYSES OF THE TWO CLAY FRACTIONS OF THE C₁ HORIZONS

Series	Size in microns	Chemical Composition							$\frac{\text{SiO}_2 + \text{Fe}_2\text{O}_3}{\text{Al}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$	$\frac{\text{Al}_2\text{O}_3}{\text{Fe}_2\text{O}_3}$	Free Fe ₂ O ₃ %	T.E.C. m.e./100g.
		SiO ₂ %	Al ₂ O ₃ %	Fe ₂ O ₃ %	CaO %	MgO %	K ₂ O %						
Catena A													
Maleb	2 - 0.2	55.7	19.0	7.6	1.5	2.2	2.5	4	5	7	3.5	47.2	
	<0.2	50.3	18.9	10.3	1.9	2.4	1.8	4	5	5	4.4	76.7	
Malez	2 - 0.2	56.2	18.9	7.8	1.4	2.2	2.5	5	5	8	3.9	48.3	
	<0.2	49.7	19.1	11.5	2.0	2.2	1.8	4	4	6	6.7	72.6	
Hemaruka	2 - 0.2	62.7	17.0	5.1	1.4	1.4	2.4	6	6	10	2.4	35.8	
	<0.2	51.5	18.3	9.9	2.1	1.9	0.9	4	5	6	5.4	70.5	
Halliday	2 - 0.2	58.7	18.5	6.2	1.3	1.8	2.4	5	5	8	2.7	44.8	
	<0.2	50.5	19.0	9.6	2.1	2.0	1.3	4	5	7	6.8	69.1	
Catena B													
Hanalta	2 - 0.2	56.4	19.0	7.5	1.4	2.0	2.2	5	5	9	4.1	46.9	
	<0.2	49.4	19.7	11.2	2.0	1.9	1.6	4	4	7	6.8	69.1	
Dowling	2 - 0.2	54.3	20.4	7.5	1.4	2.1	2.7	4	5	8	3.6	42.1	
	<0.2	48.1	20.8	10.1	1.9	2.1	2.2	3	4	7	5.4	62.2	
Parr	2 - 0.2	54.8	20.2	7.5	1.2	2.2	2.6	4	5	8	3.7	41.9	
	<0.2	48.3	21.0	10.1	1.9	2.0	2.1	3	4	7	5.4	64.4	
Earltown	2 - 0.2	56.9	19.2	8.2	1.0	1.8	2.7	5	5	9	4.6	36.7	
	<0.2	48.8	19.5	11.6	1.7	2.0	1.4	4	4	6	6.8	71.6	

Mineralogical and Chemical Composition of the Light Sand Fractions

The x-ray diffraction patterns obtained for the light sand fractions from the C₁ horizons of the profiles are shown in Figure 1. The diffraction patterns show the presence of potash and soda-calcic feldspars and quartz in the samples. The data suggest that there are no qualitative differences in mineralogical composition of the light sand fractions from the parent materials of the different profiles.

The chemical compositions of the light sand (sp.gr. < 2.70) fractions from the C₁ horizons of the profiles are presented in Table III. The Hanalta series was not included because of insufficient sample. In the profiles analysed both the amounts of the chemical constituents by determination and the calculated amounts of feldspar show as large a variation within each suggested catena as between the two catenas. The data apparently indicate that the two suggested catenas cannot be distinguished by chemical composition of the light sand fractions in the C₁ horizons.

Mechanical Composition of the Profiles

Mechanical analyses data for the soil profiles are presented in Table IV. The C horizons from the members of Catena B appear to have larger variations in mechanical composition than do the C horizons from the members of Catena A. Mechanical compositions of the C and D horizons from the members of Catena B are similar. The data therefore

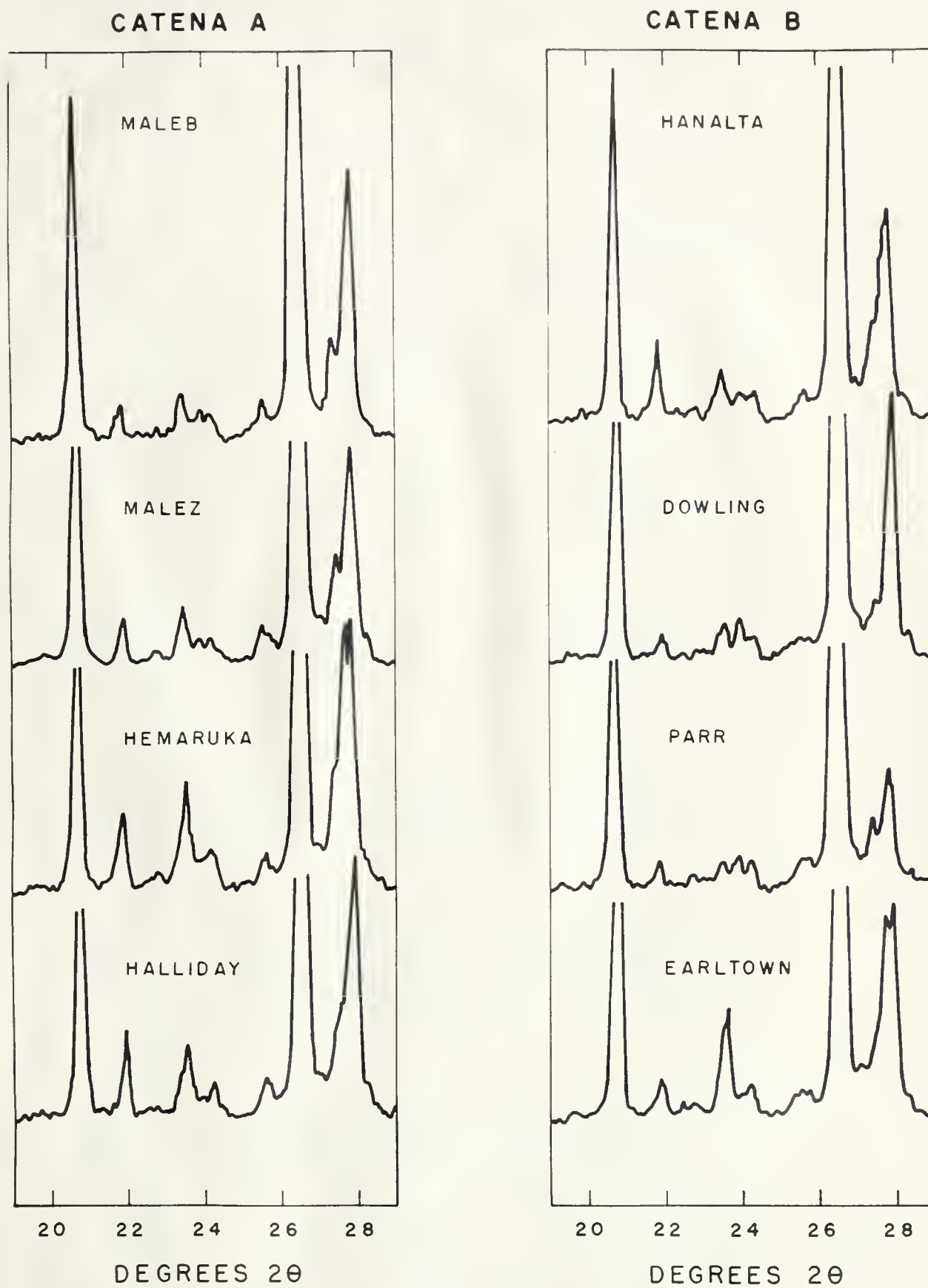


Figure 1. - X-ray diffraction patterns of light sands from the C_1 horizons.

TABLE III - CHEMICAL COMPOSITION OF THE LIGHT SAND FRACTIONS OF THE C₁ HORIZONS

Series	SiO ₂ %	Al ₂ O ₃ %	Fe ₂ O ₃ %	CaO %	Na ₂ O %	K ₂ O %	K-Feldspar %	Na+Ca-Feldspar %
Catena A								
Maleb	85.0	8.0	0.8	1.6	1.4	1.6	9	20
Malez	84.3	8.3	0.9	1.4	1.4	1.6	10	19
Hemaruka	80.7	10.8	0.7	2.1	2.0	1.9	11	27
Halliday	82.5	9.9	0.6	2.0	2.0	1.8	11	27
Catena B								
Dowling	87.4	6.4	0.6	1.7	1.2	1.3	8	18
Parr	88.5	6.1	0.5	1.4	1.1	1.2	8	16
Earltown	82.0	10.4	0.6	1.7	2.1	1.9	11	26

1
30
1

TABLE IV - MECHANICAL COMPOSITION OF THE PROFILES

Catena A							Catena B						
Series	Hor- izon	Depth, inches	%S	%Si	%C	%O.2uC	Series	Hor- izon	Depth, inches	%S	%Si	%C	%O.2uC
Maleb	Al B2 Cca Cl Csa C2 C3	Orthic					Hanalta	Al B2 Cca Cl D1 D2	Orthic				
		0-2	55	22	23	8			0-6	33	41	26	-
		2-10	50	23	27	15			6-15	48	27	25	-
		10-18	52	25	23	8			15-33	51	28	21	-
		18-36	50	24	26	14			at 40	22	48	30	17
		44-48	44	27	29	13			at 60	51	25	24	10
		72-78	43	26	31	12			at 144	55	27	18	5
		at 150	47	30	23	12							
Malez	Al B2 Cca Cl C2 C3	Solonetz-like					Dowling	Al B2 Cca Cl D1 D2	Solonetz-like				
		0-3	42	30	28	13			0-4	58	30	12	-
		3-13	37	26	37	22			4-12	42	22	36	-
		13-20	34	39	27	11			12-20	41	28	31	-
		20-36	48	24	28	16			at 20	41	27	32	18
		48-52	46	30	24	10			at 48	42	25	33	16
		at 126	46	31	23	13			at 138	46	24	30	14

TABLE IV - CONTINUED

Catena A							Catena B						
Series	Hor- izon	Depth, inches	%S	%Si	%C	%O.2uC	Series	Hor- izon	Depth, inches	%S	%Si	%C	%O.2uC
Solodized-Solonetz							Solodized-Solonetz						
HemaruKa	A1	0-3	59	27	14	-	Parr	A1	0-10	62	26	16	-
	A2	3-6	60	29	11	-		A2	10-12	70	17	13	-
	B2	6-9	27	30	43	-		B2	12-16	59	18	23	-
	B3	9-15	12	33	55	-		B3	16-24	69	11	20	-
	Cca	15-26	13	39	48	-		Cca	24-31	50	25	25	-
	C1	at 26	48	20	32	13		C1	31-40	49	28	23	16
	C2	at 72	49	23	28	12		C2	at 132	44	30	26	16
Solod							Solod						
Halliday	A1	0-12	37	38	25	-	Earltown	A1	0-6	36	48	16	7
	A2	12-15	57	33	10	-		A12	6-13	44	44	12	5
	B2	15-19	22	54	24	-		A13	13-18	25	49	26	15
	Cca	19-25	64	13	23	-		A2	18-22	24	53	23	14
	C1	at 30	50	25	25	11		B2	22-34	39	33	28	18
	C2	at 138	46	29	25	10		C1	34-42	53	33	14	10
								D	at 72	77	15	8	0

appear not to distinguish two parent materials of distinctly different mechanical composition for the two suggested catenas.

The textural patterns of the soil profiles aid in the classification of the soils into distinct member profiles. The Orthic profiles do not show horizons of either clay removal or accumulation. The Solonetz-like profiles are distinguished from the Orthic profiles by clay accumulations in the B horizons. The Solodized-Solonetz and Solod profiles show horizons of clay removal and clay accumulation. The Solod profiles are differentiated by more deeply developed A horizons than the Solodized-Solonetz profiles. The data therefore show characteristic textural patterns for each member profile.

Disturbed Hydraulic Conductivity of the Profile Samples

Disturbed hydraulic conductivity data for the profile samples are shown in Figure 2. The member profiles of Catena B appear to have larger variations in C horizon hydraulic conductivity than have the corresponding members of Catena A. The soil profiles may be placed in two permeability groups on the basis of the hydraulic conductivity data for the sola. Orthic and Solonetz-like profiles have roughly similar patterns of hydraulic conductivity values. Their decreases in hydraulic conductivity down to and including the B₂ horizons are much smaller than those in the Solodized-Solonetz and Solod profiles. The Orthic and Solonetz-like profiles therefore appear to have

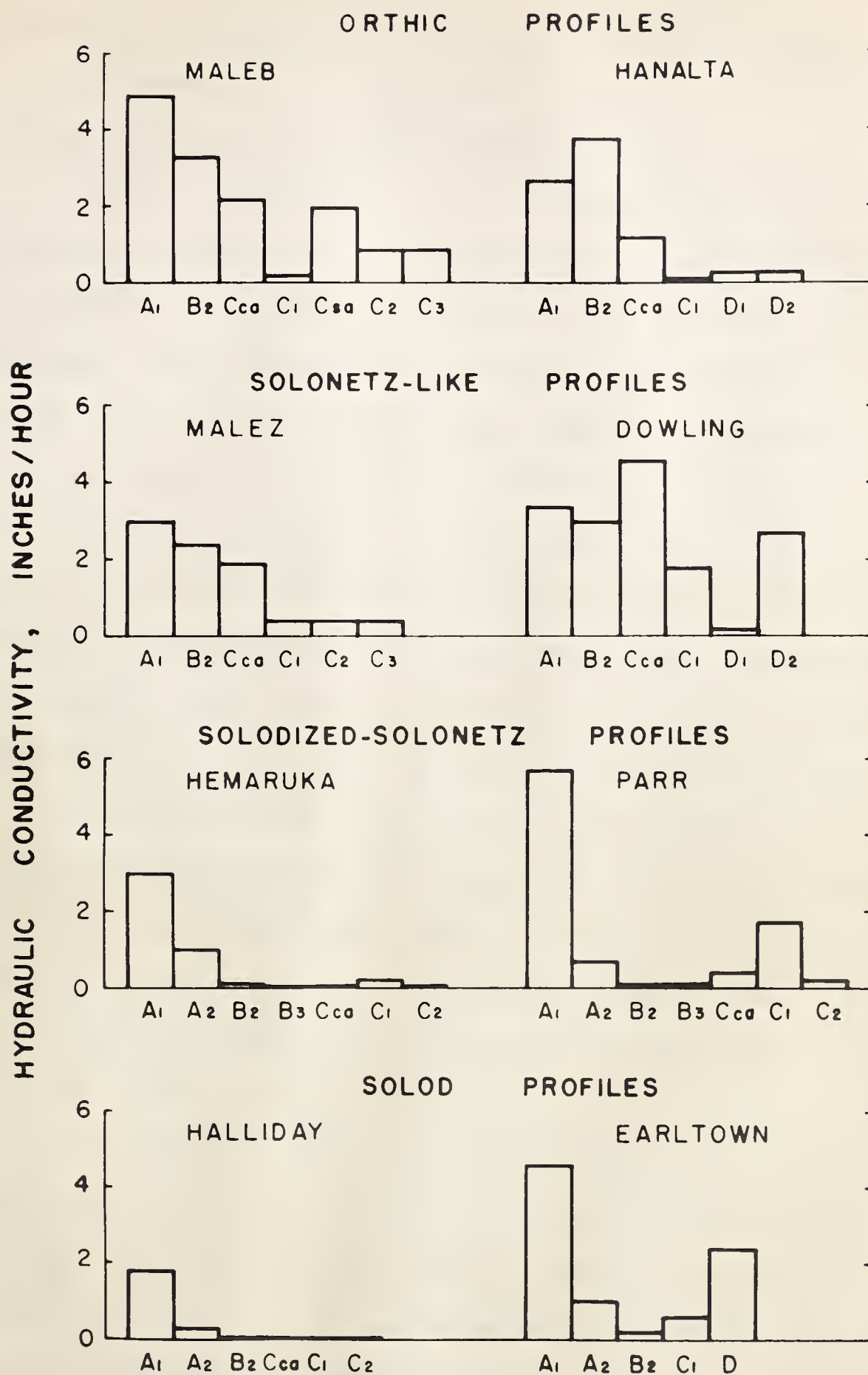


Figure 2. - Hydraulic conductivity of the profile samples.

B horizons with greater permeability than the B horizons of the Solodized-Solonetz and Solod profiles.

Soluble Cations of Saturated Water Extracts

Water soluble salt data for the soil profiles are presented in Table V. The Orthic profiles have relatively low amounts of soluble salts down to and including the C_1 horizons. The Solonetz-like profiles have relatively low soluble salt contents throughout. The Solodized-Solonetz profiles have relatively high soluble salt contents throughout. The Solod profile in Catena A exhibits a high salt content very similar to those of the Solodized-Solonetz profiles. The Solod profile in Catena B has a low soluble salt content which may be a feature of the more advanced stage of development that this profile appears to show.

The proportions of soluble sodium as shown by the sodium-adsorption-ratios are higher in the B horizons of the Solodized-Solonetz and Solod profiles than in the B horizons of the Orthic and Solonetz-like profiles. The data therefore suggest characteristic soluble salt distributions for each of the member profiles.

The proportions of soluble sodium and magnesium expressed as per cent of cations in the saturated extract are shown for the different member profiles in Figures 3, 4 and 5. Soluble sodium and soluble sodium plus magnesium percentages shown in Figure 3 are higher in the B_2 horizons of the Solodized-Solonetz and Solod profiles than those in

TABLE V - SOLUBLE CATIONS OF SATURATED WATER EXTRACTS

Catena A							Catena B						
Series	Hor-izon	Ca	Mg	Na	Total	S.A.R.	Series	Hor-izon	Ca	Mg	Na	Total	S.A.R.
Maleb	B2 Cca C1 Csa C2 C3	4 3 1 24 22 17	Orthic 3 2 1 31 52 21	1 1 7 28 63 34	8 6 9 83 137 72	<1 1 7 5 10 8	Hanalta	B2 Cca C1 D1 D2	3 5 1 66 26	Orthic 2 3 4 71 38	1 1 16 48 43	6 9 21 185 107	<1 2 10 6 9
Malez	B2 Cca C1 C2 C3	3 2 1 1 24	3 2 1 <1 24	Solonetz-like 1 2 4 4 16	7 6 6 5 64	1 2 4 5 3	Dowling	B2 Cca C1 D1 D2	4 2 1 1 23	Solonetz-like 3 3 3 1 33	2 2 4 11 33	9 7 8 13 89	1 1 3 11 6
Hemaruka	B2 B3 Cca C1 C2	5 25 26 23 21	Solodized-Solonetz <1 11 11 9 9	24 59 63 63 56	29 95 100 95 86	16 14 15 16 14	Parr	B2 B3 Cca C1 C2	1 15 24 1 22	Solodized-Solonetz 2 50 67 4 18	15 76 83 1 44	18 141 174 6 84	14 13 12 1 10
Halliday	B2 Cca C1 C2	4 8 2 20	Solod 3 17 1 9	58 140 21 59	65 165 24 88	33 40 17 15	Earltown	B2 C1 D	<1 <1 1	Solod 1 1 1	2 3 5	3 5 7	3 3 5

Soluble cations are expressed in m.e. per liter
S.A.R. - Sodium-Adsorption-Ratio

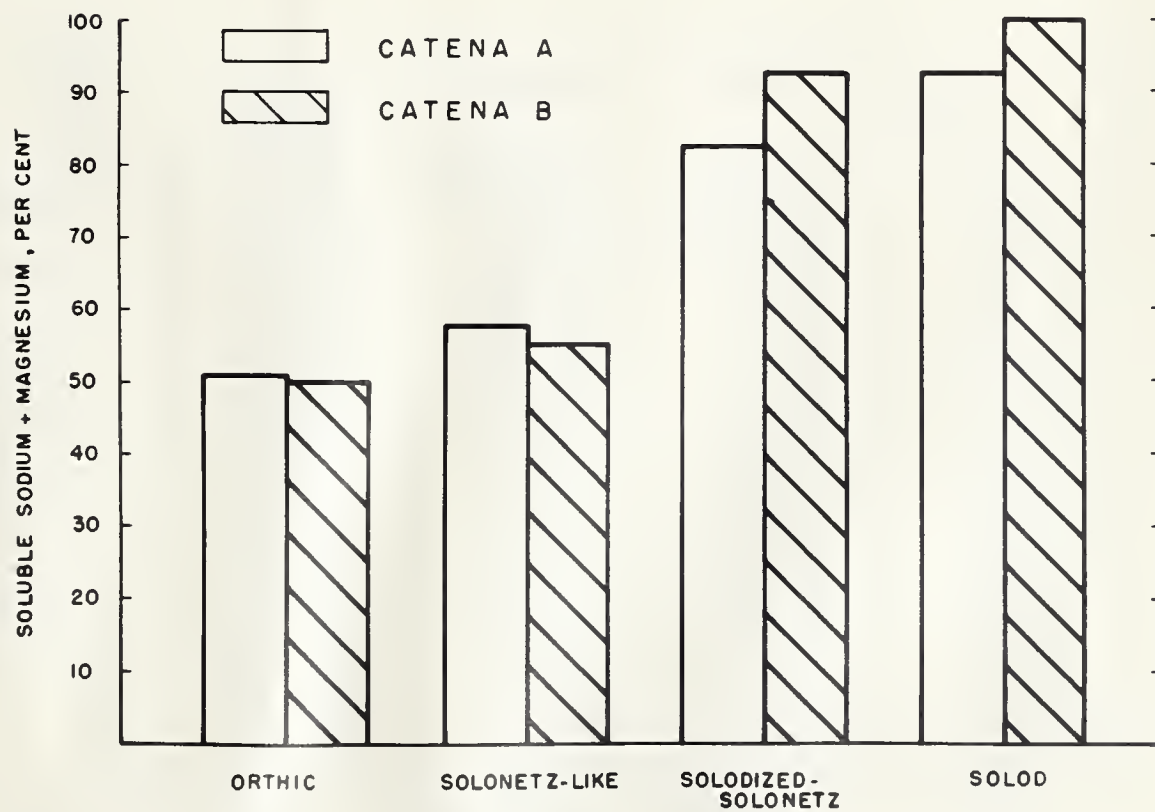
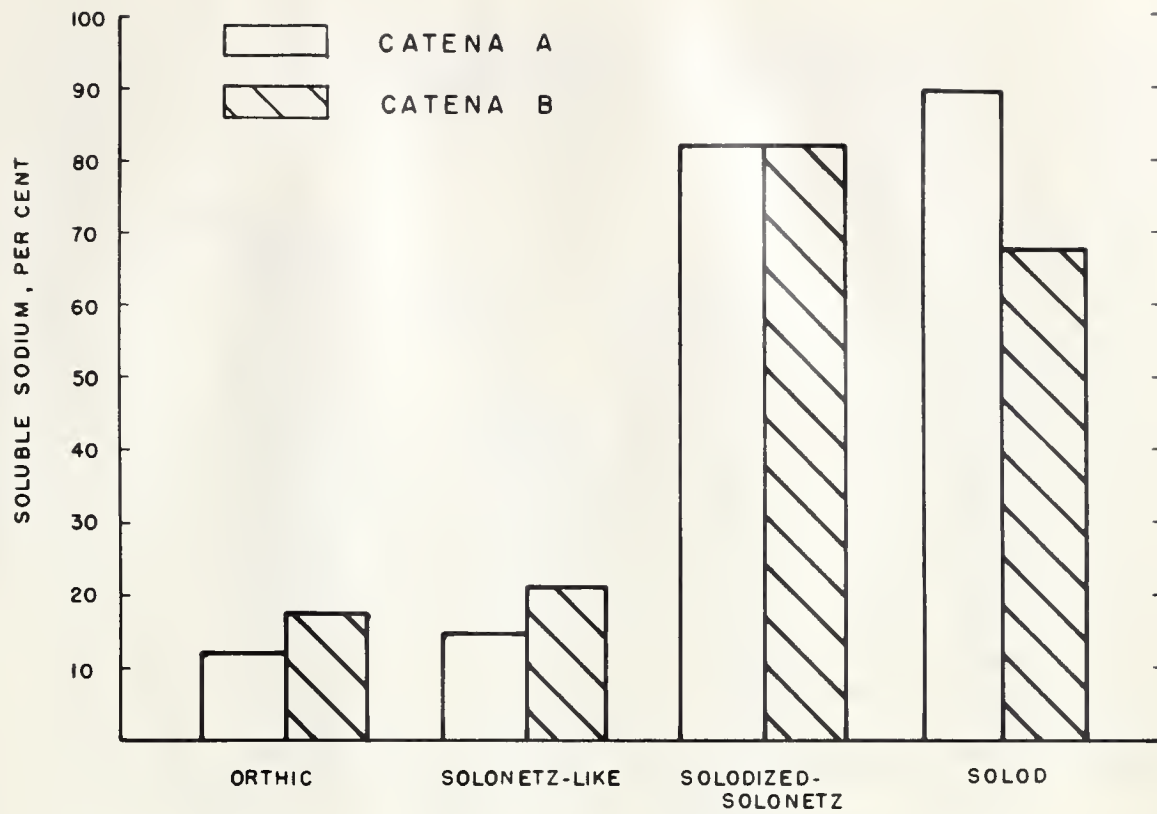


Figure 3. - Soluble sodium and magnesium in B₂ horizons of member profiles, expressed as per cent of total cations in saturated extract.

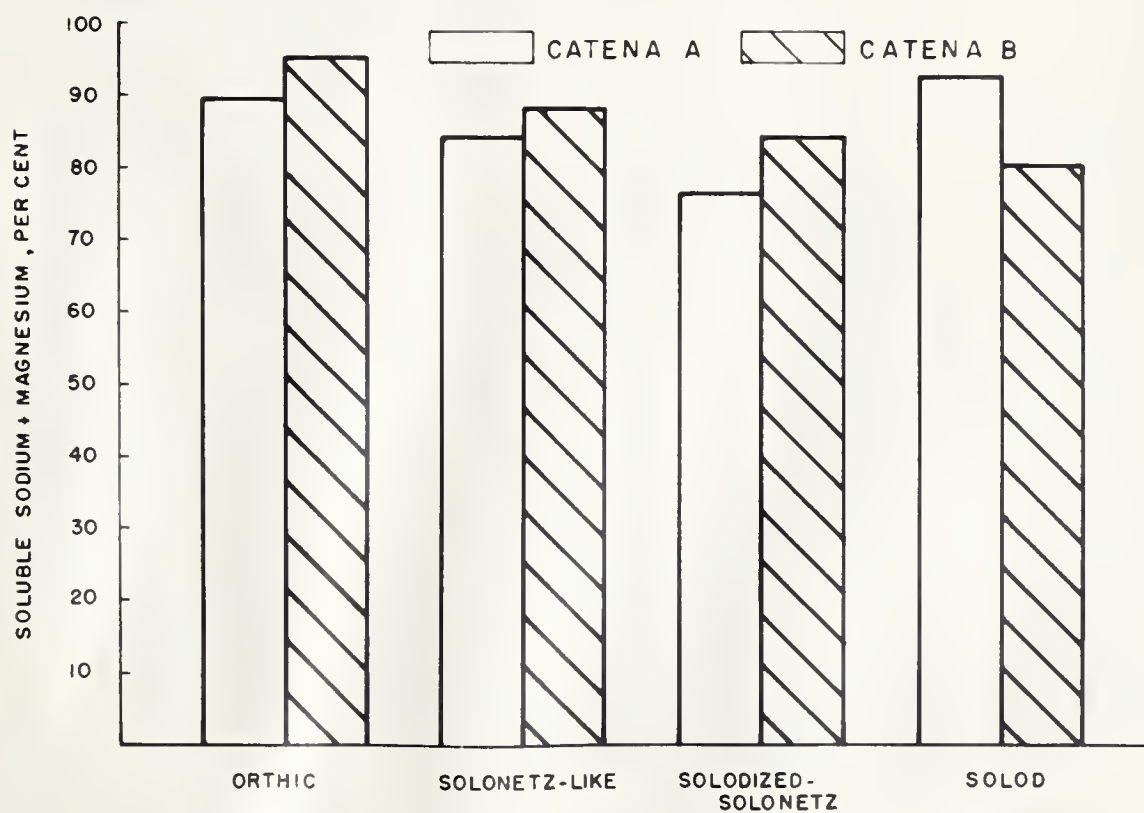
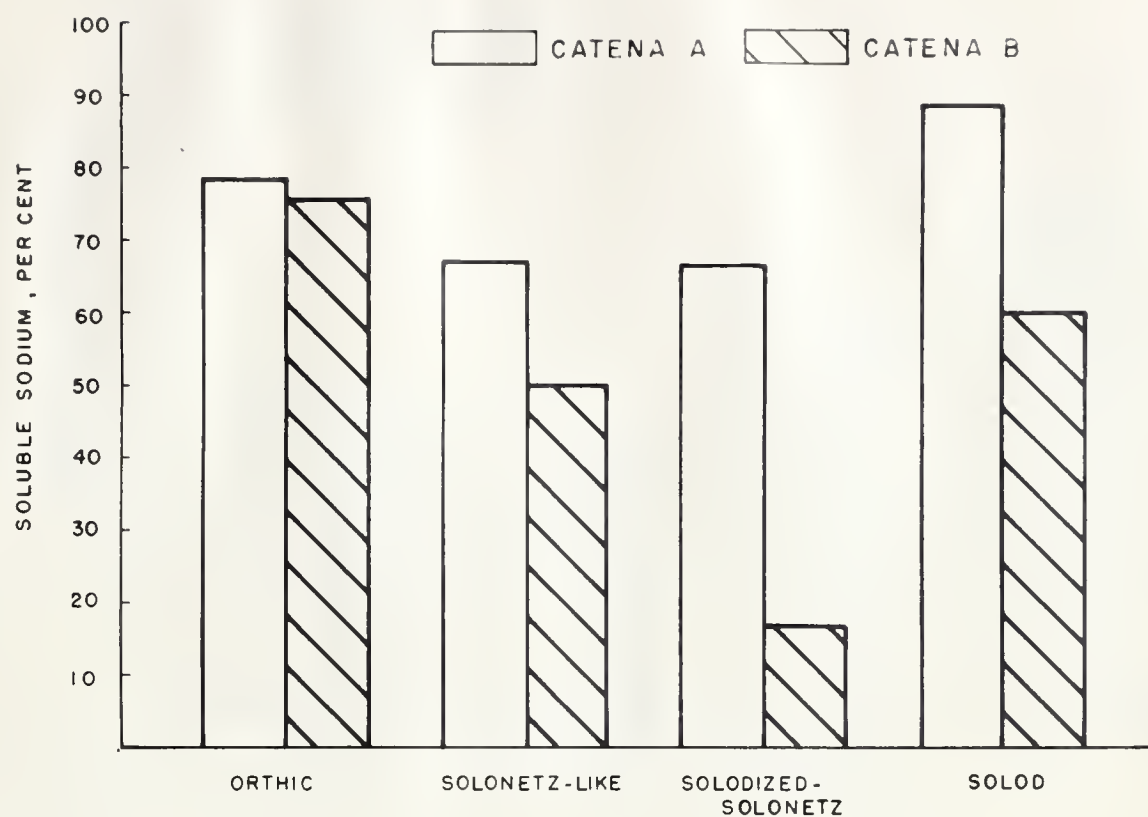


Figure 4. - Soluble sodium and magnesium in C₁ horizons of member profiles, expressed as per cent of total cations in saturated extract.

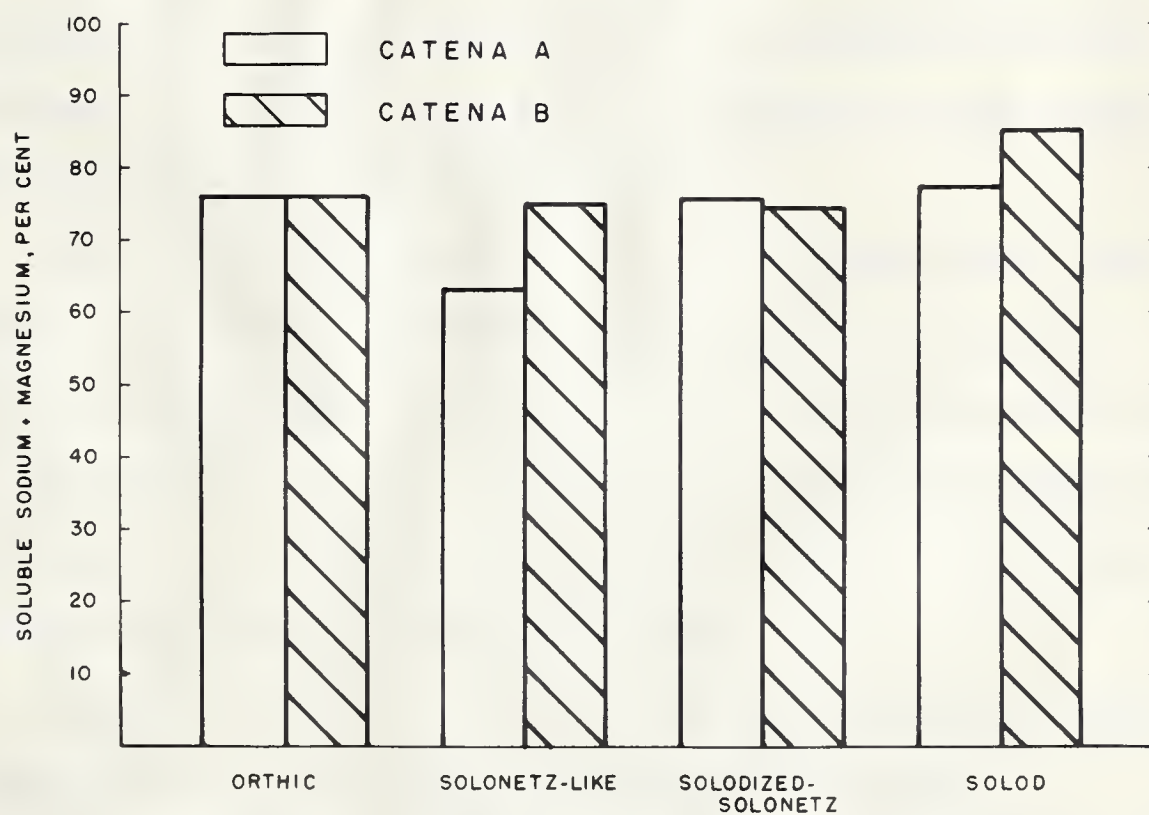
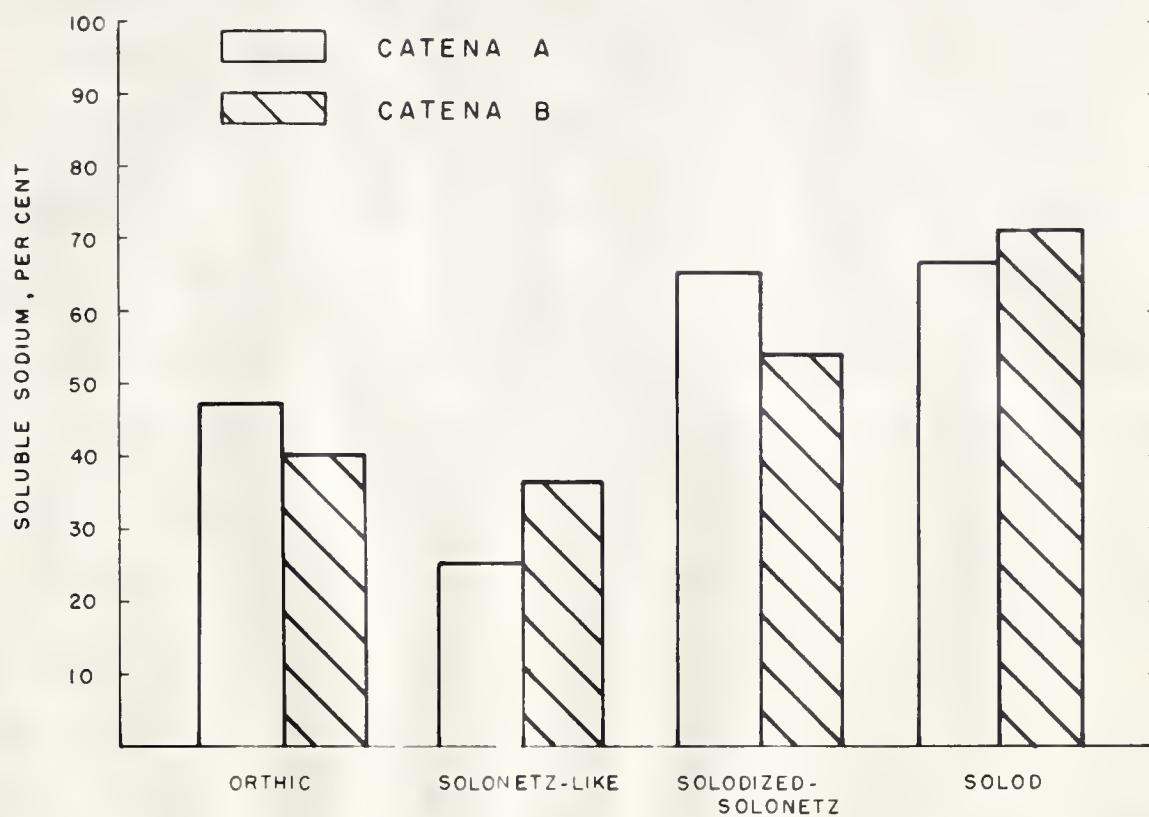


Figure 5. - Soluble sodium and magnesium in deep samples of materials underlying C_1 horizons of member profiles, expressed as per cent of total cations in saturated extract.

the B₂ horizons of the Orthic and Solonetz-like profiles.

Figure 4 shows the percentages of soluble sodium to be more variable than the percentages of soluble sodium plus magnesium in the C₁ horizons of the different member profiles. However, the percentages of soluble sodium in the C₁ horizons of the Orthic and Solonetz-like profiles are for the most part equal to or greater than those in the C₁ horizons of the Solodized-Solonetz and Solod profiles.

Figure 5 shows that the percentages of soluble sodium in the deep samples of the materials underlying the C₁ horizons tend to be only slightly lower for the Orthic and Solonetz-like profiles than those for the Solodized-Solonetz and Solod profiles. The percentages of soluble sodium plus magnesium in the C₁ horizons appear to be similar to the percentages of soluble sodium plus magnesium in the underlying materials of each member profile.

The data from Figures 3, 4 and 5 suggest that percentages of soluble sodium and magnesium in the parent materials of different member profiles are similar and that any redistribution in the proportions of soluble sodium and magnesium due to leaching has occurred only in the sola of the Orthic and Solonetz-like profiles.

Several workers (9, 20, 5, 33) have discussed the importance of soluble sodium and magnesium in the formation of Solonetzic soils. The ratios of soluble sodium and magnesium to calcium in the parent materials of the

different member profiles concerned appear to be similar. The low total amounts of soluble salts present in the parent materials of the Orthic and Solonetz-like member profiles seem to be one of the main factors responsible for their different morphological features as compared to those of the Solodized-Solonetz and Solod profiles.

Exchangeable Cations of the Soil Profiles

The exchangeable cation data for the soil profiles are given in Table VI. Exchangeable acidity distributions for the soil profiles suggest an increasing degree of leaching and replacement of exchangeable bases by hydrogen in the different member profiles proceeding from Orthic through to Solod profiles. Exchangeable acidity, reported as exchangeable hydrogen, is present in greater amounts in the A₁ horizons of the Solonetz-like profiles than in the A₁ horizons of the Orthic profiles. There are approximately equal amounts of exchangeable acidity in the A horizons of the Solodized-Solonetz as in the Solod profiles, and the amounts are higher than those in the A₁ horizons of the Orthic profiles. The relatively deeper developed A horizon of the Solod profiles suggests a further stage of development in those profiles as compared to the Solodized-Solonetz profiles. The exchangeable acidity data therefore help substantiate the field separations of the profiles made on the basis of morphological features.

Exchangeable potassium does not appear to have a

TABLE VI - EXCHANGEABLE CATIONS OF THE PROFILES

Catena A										Catena B											
Series	Hor- izon	Total		Per Cent of						Series	Hor- izon	Total		Per Cent of							
		C.E.C.*		Total C.E.C.**								C.E.C.*		Total C.E.C.**							
		Sum. Deter.		H	Na	K	Ca	Mg				Sum. Deter.		H	Na	K	Ca	Mg			
Maleb	A1 B2	Orthic	24.9	21.4	8	0	4	70	18	Hanalta	A1 B2	Orthic	33.7	22.6	0	<1	4	87	9		
			24.9	21.2	<1	1	4	69	26				20.3	19.5	2	1	3	72	22		
			Solonetz-like										Solonetz-like								
			22.2	23.2	14	0	9	54	23				9.1	8.9	29	5	3	40	23		
Malez	A1 B2	Orthic	33.1	27.6	1	2	9	55	33	Dowling	A1 B2	Solonetz-like	28.3	20.5	<1	10	3	62	25		
			Solodized-Solonetz										Solodized-Solonetz								
Hemaruka	A1 A2 B2 B3	Orthic	13.9	14.0	25	1	6	53	15	Parr	A1 A2 B2 B3	Solod	12.2	10.9	12	2	3	56	27		
			7.1	7.2	16	25	1	41	17				8.0	6.4	9	9	4	44	28		
			31.9	30.0	0	33	2	37	28				14.0	13.2	2	16	6	34	42		
			62.4	35.5	0	20	2	60	18				16.7	12.8	0	16	5	26	53		
Halliday	A1 A2 B2	Orthic	23.5	23.0	10	<1	6	64	20	Earltown	A1 A12 A13 A2 B2	Solod	25.1	23.4	16	0	8	60	16		
			7.6	6.2	5	33	7	24	31				14.2	15.3	16	1	11	51	21		
			16.6	16.3	0	32	7	16	45				20.1	20.3	12	1	10	50	27		
			Solodized-Solonetz										Solodized-Solonetz								

regular variation in the different member profiles, but is present in relatively high proportions throughout the Solod profile in Catena B. Calcium is the dominant exchangeable cation in the Orthic profiles.

The proportions of exchangeable sodium and magnesium expressed as per cent of total cation exchange capacity by summation are shown for the different member profiles in Figure 6. Exchangeable sodium and exchangeable sodium plus magnesium percentages are higher in the B₂ horizons of the Solodized-Solonetz and Solod profiles than in the B₂ horizons of the Orthic and Solonetz-like profiles. Distributions of exchangeable sodium and magnesium appear to be similar to the distributions of soluble sodium and magnesium in the B₂ horizons of each member profile.

The exchangeable sodium percentages in the B₂ horizons of the Solodized-Solonetz and Solod member profiles of Catena B are lower than those in the B₂ horizons of the corresponding members of Catena A. The Solodized-Solonetz and Solod profiles from Catena B have relatively deeper A than B horizons and more deeply developed sola than have the corresponding members of Catena A. The data appear to show some relationship between per cent exchangeable sodium in the B₂ horizons and degree of sola development in the Solodized-Solonetz and Solod member profiles.

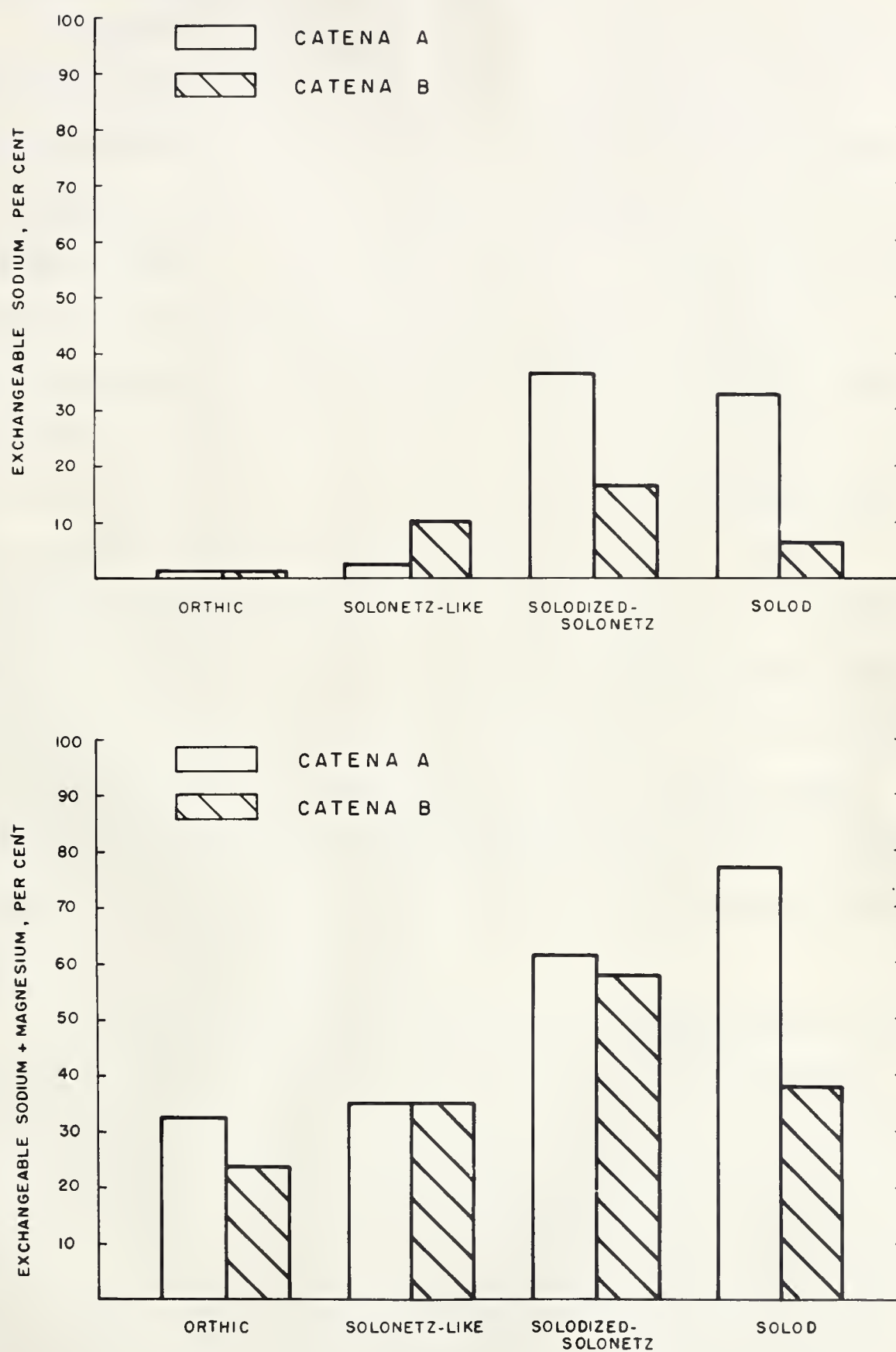


Figure 6. - Exchangeable sodium and magnesium in the B₂ horizons of member profiles, expressed as per cent of total cations in ammonium acetate extract.

Chemical Analyses of the Soil Profiles

Chemical analyses of the soil profiles in Catena A and Catena B are given in Table VII. The pH values for the A and B horizons of the different member profiles suggest an increasing degree of leaching proceeding from the Orthic profiles through to the Solod profiles. The Solonetz-like profiles are distinguished from the Orthic profiles by having moderately acid pH values for the A_1 horizons and mildly acid to neutral pH values for the B_2 horizons. Most of the A_1 and A_2 horizons of the Solodized-Solonetz and Solod profiles have moderately acid pH values. The moderately acid pH value for the B_2 horizon of the Solod profile in Catena B suggests greater leaching than in the B_2 horizon of the Solod profile in Catena A. Most of the pH values of the C horizons range closely around eight. The C_1 horizon of the Solod profile from Catena B has a neutral pH value which suggests a lower base saturation than those of the other parent materials.

The calcium-carbonate-equivalent percentages in the C_1 horizons of the Orthic, Solonetz-like and Solodized-Solonetz member profiles of Catena B are higher than those in the C_1 horizons of the corresponding member profiles of Catena A. The C_1 horizon of the Solod profile from Catena B has a lower calcium-carbonate-equivalent per cent than that in the C_1 horizon of the Solod profile from Catena A.

TABLE VII - CONTINUED

Catena A							Catena B						
Series	Hor- izon	pH	Total Nitrogen %	Organic Carbon %	C/N	CaCO ₃ Equi- valent %	Series	Hor- izon	pH	Total Nitrogen %	Organic Carbon %	C/N	CaCO ₃ Equi- valent %
Solodized-Solonetz							Solodized-Solonetz						
Hemaruka	A ₁	5.6	0.26	3.46	13	0.0	Parr	A ₁	6.2	0.13	1.82	14	0.0
	A ₂	6.5	0.07	0.82	12	0.0		A ₂	6.4	0.05	0.59	12	0.0
	B ₂	7.7	0.13	1.33	10	0.0		B ₂	7.1	0.07	0.73	10	0.0
	B ₃	8.0	0.17	2.28	13	0.0		B ₃	8.2	0.03	0.46	14	0.0
	C _{ca}	7.9	-	-	-	1.4		C _{ca}	8.3	-	-	-	1.4
	C ₁	7.7	-	-	-	1.2		C ₁	8.3	-	-	-	6.6
	C ₂	7.7	-	-	-	1.2		C ₂	7.7	-	-	-	4.3
Solod							Solod						
Halliday	A ₁	6.4	0.42	5.04	12	0.0	Earltown	A ₁	6.0	0.42	5.17	12	0.0
	A ₂	7.0	0.06	0.54	9	0.0		A ₁₂	5.7	0.13	1.11	9	0.0
	B ₂	8.1	0.08	0.75	10	0.0		A ₁₃	5.5	0.13	1.35	11	0.0
	C _{ca}	8.6	-	-	-	1.5		A ₂	5.7	0.07	0.62	9	0.0
	C ₁	8.4	-	-	-	1.3		B ₂	6.1	0.06	0.61	10	0.0
	C ₂	7.8	-	-	-	8.4		C ₁	7.0	-	-	-	0.1
								D	8.1	-	-	-	0.2

The data appear to partially corroborate the field separation of Catena B from Catena A on the basis of more limy parent materials in Catena B than the parent materials of the corresponding member profiles of Catena A.

Stobbe (29) has stated that removal of inorganic carbonates is necessary before soil profile development can proceed. The low calcium-carbonate-equivalent percentages found in the C_1 horizons of the Solod member profiles may have allowed further solodization in these profiles than in the Solodized-Solonetz profiles. Lower calcium-carbonate-equivalent per cent and higher permeability in the C_1 horizon of the Solod member from Catena B than in the C_1 horizon of the Solod member from Catena A may have permitted the advanced stage of development mentioned for this profile in the preceding discussion of soluble salt data.

Total nitrogen and organic carbon percentages vary widely in the A and B horizons of the different member profiles. The A_2 horizons of the Solodized-Solonetz and Solod profiles are distinguished by relatively lower amounts of total nitrogen and organic carbon than in their A_1 and B_2 horizons. The C/N ratios are variable for the A and B horizons of the Orthic and Solonetz-like profiles. The C/N ratios in the Solodized-Solonetz profiles are lowest in the B_2 horizons. The C/N ratios in the Solod profiles are lowest in the A_2 horizons. The nitrogen and carbon data show the effect of leaching in the Solodized-Solonetz and Solod member profiles.

SUMMARY AND CONCLUSIONS

The objectives of the study were to find out firstly, whether or not differences in the composition of parent materials could justify separation of the soil profiles concerned into two catenas; and secondly, whether or not variations in the composition of parent materials were related to the stages of Solonetzic development of the profiles as revealed by morphological features and laboratory analyses.

Comparison of Parent Materials from the Two Suggested Catenas

The two clay fractions from the C_1 horizons of the eight soil series making up the four different member profiles of Catena A and Catena B were all similar in mineralogical composition. X-ray diffraction patterns showed that the fine clay fractions had higher contents of montmorillonite than the coarse clay fractions in all the C_1 horizons. Chemical analyses of the two clay fractions from each of the C_1 horizons gave further evidence for the higher proportions of montmorillonite in the fine clay fractions. Chemical composition of the light sand fractions from each of the C_1 horizons did not show any regular variation among the different member profiles of both suggested catenas.

Mechanical compositions and disturbed permeabilities for the different C_1 horizons did not show any regular variation either within or between the two suggested catenas.

However, higher calcium-carbonate-equivalent percentages in the C_1 horizons suggested more limy parent materials for the Orthic, Solonetz-like, and Solodized-Solonetz member profiles of Catena B than for the corresponding member profiles of Catena A. The Solod profile from Catena B was the exception with less limy parent material than the Solod profile from Catena A.

In conclusion, mineralogical and physical data obtained for the C_1 horizons of the soil profiles concerned failed to differentiate either the two suggested catenas or the different member profiles. The higher lime content in the parent materials of some members of Catena B than in the parent materials of the corresponding members of Catena A partially justified the separation of Catena B from Catena A.

Relation Between Morphological Features of the Soil Profiles and Laboratory Data for the Soil Sola

Mechanical analyses data for the soil sola showed characteristic textural patterns for each member profile. Disturbed hydraulic conductivity data suggested that the B horizons of the Orthic and Solonetz-like member profiles were more permeable than the B horizons of the Solodized-Solonetz and Solod member profiles.

Water soluble salt data suggested characteristic variations in composition of soluble salts for the different member profiles and some variation in soluble salt composition

for the degree of development of Solod member profiles. The distributions of exchangeable cations in the soil profiles appeared to vary according to the characteristic morphology of each member profile.

The pH data for the soil profiles suggested that different amounts of leaching had occurred in different member profiles. Nitrogen and organic carbon data gave further evidence of leaching in the Solodized-Solonetz and Solod member profiles.

In conclusion, laboratory data obtained for the soil sola corroborated the division of the soil profiles into different member profiles and gave some evidence for different degrees of profile development in the Solod member profiles.

Relation Between Stage of Solonetzic Development and Variations in Composition of Parent Materials

Soluble salt data suggested that the proportions of soluble sodium and magnesium present in the parent materials of the different member profiles were all similar. Since the proportions of soluble sodium and magnesium appeared to be similar for all the parent materials, the low total amounts of soluble salts in the parent materials of the Orthic and Solonetz-like member profiles were concluded to be a primary factor for development of different morphology as compared to the Solodized-Solonetz and Solod member profiles.

The analyses conducted on the soil profiles concerned showed sufficient differences in composition of parent materials to differentiate the Orthic and Solonetz-like profiles from the Solodized-Solonetz and Solod profiles. The analyses did not show sufficient differences in parent material composition to separate the Solonetz-like profiles from the Orthic profiles or the Solod profiles from the Solodized-Solonetz profiles.

There is a possibility that other factors are responsible for the presence of Solonetz-like profiles instead of Orthic profiles and for the presence of Solod profiles instead of Solodized-Solonetz profiles. Study of the role of topography in relation to microclimatic, vegetational and soil patterns might supply differentiating characteristics in the development of the Orthic and Solonetz-like profiles. Detailed study of soil porosity in relation to internal and external drainage may give more insight into conditions which have produced Solod profiles instead of Solodized-Solonetz profiles in the area concerned in this study.

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